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The Effects of Forest Harvesting on Small mammals in Western Newfoundland and its Significance to Marten

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THE EFFECTS OF FOREST HARVESTING ON SMALL MAMMALS IN WESTERN NEWFOUNDLAND AND ITS SIGNIFICANCE TO MARTEN

by

Brian John Tucker

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Fisheries and Wildlife

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1988

Dedicated to the memory of Terri L. Steel, fellow graduate student, who died suddenly May 28, 1988. Her friendship and kindness will be remembered always.

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Brian John Tucker

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ABSTRACT

The Effects of Forest Harvesting on Small mammals in Western Newfoundland and its Significance to Marten

by

Brian Tucker, Master of Science

Utah State University, 1988

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Department: Fisheries and Wildlife

The depauperate fauna of Newfoundland provides a limited prey base for marten. Only two small mammal prey species, *Microtus pennsylvanicus* and *Sorex cinereus*, were found in any abundance in the old-growth forests of the study area. Of these two, *Microtus* displayed population fluctuations typical of most microtines. Analysis of marten scats indicated that *Microtus* is a very important prey item to the marten with other food items being of lesser importance particularly when *Microtus* are abundant.

Trapping in various habitats indicated that *Sorex* densities were three to five times higher in logged areas compared to uncut areas. Unfortunately, the effects of logging on *Microtus* could not be determined directly from this study. *Microtus* numbers declined drastically in the spring of 1987, apparently independently of logging operations. *Microtus* numbers dropped from a density of 25.0 per hectare in the spring of 1986 to virtually zero in the spring of

1987. This reduction may be linked to an outbreak of viral encephalitus in the marten population in the fall of 1986.

Marten (*Martes americana*) prefer mature coniferous and mixed forests and utilize regenerating cutovers minimally. The reasons for this are unclear, although prey abundance and availability may be involved. In this study, *Sorex* were more abundant in regenerating cutovers and the literature suggests that *Microtus* are also more abundant in these areas. This would seem to suggest that prey abundance above certain threshold densities is not critical to marten habitat selection. However, prey availability may play a more important role. Although prey species may be more abundant in logged areas, prey availability may be reduced.

(52 pages)

INTRODUCTION

Marten (Martes americana) are indigenous to the province of Newfoundland. Although never abundant, marten were once found in most forested areas of the province (Bergerud, 1969; Snyder, 1985). In the early 1900's, a decline in the marten population was noticeable (Snyder, 1985). By 1934, their numbers were sufficiently low to warrant the closing of the marten trapping season; the season has never been reopened. Despite the closure of the trapping season, marten numbers and distribution continued to decline. In 1973, the Newfoundland and Labrador Wildlife Division established a Pine Marten Study Area (PMSA) in the Grand Lake-Little Grand Lake region of western Newfoundland. This area was considered to be one of the few areas remaining that still contained a remnant population; distribution studies have confirmed this (Mayo, 1975; Mayo, 1984; Snyder and Hancock, 1982). Within the PMSA, marten are protected, but their habitat is not. All trapping and snaring are prohibited within the PMSA to protect marten from accidental capture. In 1986, due to their long-term decline in numbers and distribution, marten in Newfoundland were listed as "threatened" on the list of endangered wildlife in Canada by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Major factors contributing to the early decline of marten in Newfoundland are thought to have been over-trapping and habitat loss due to fire and forest harvesting (Snyder, 1985). Other factors such as accidental trapping, predation, environmental contamination from insecticides, and, a more recent finding, disease, also may be inhibiting marten recovery. However, given the specific habitat requirements of marten, habitat loss due to forest harvesting is presently thought to be the main obstacle to the marten's recovery in Newfoundland.

Marten prefer mature coniferous and mixed forests with high overstory density (Koehler and Hornocker, 1977; Soutiere, 1979; Francis and Stephenson, 1972; Mech and Rogers, 1977). The reasons for this preference are not clearly understood, but prey abundance and availability, among other things, may be important.

Large clearcuts have been shown to be detrimental to marten populations in North America and Europe (Major, 1979; Soutiere, 1979; Snyder and Bissonette, 1987). In Maine, the density of marten in commercially clearcut forest was about one-third that in undisturbed forest (Soutiere, 1979). Likewise, clearcut areas supported few marten in Ontario (de Vos, 1952; Thompson, 1986). In Wyoming, marten did not use clearcuts less than one year old (Clark and Campbell, 1977). Regenerating clearcuts in Maine were used only in the late summer when berries were present (Steventon and Major, 1982). Marten in Newfoundland concentrated their use in undisturbed forest while small, uncut residual stands greater than 15 hectares were used if available (Snyder, 1984). Regenerating clearcuts less than 23 years old received minimal use.

In recent years forest harvesting has encroached on the PMSA at a rate of 4000 hectares per year. This rate will probably increase within the next few years (C. John, pers. comm., 1985, <u>in</u>

Snyder, 1985). Corner Brook Pulp and Paper, Limited maintains that without access to its timber leases within the PMSA, the future economic viability of the Corner Brook mill is uncertain.

In Newfoundland, the depauperate fauna provides a limited prey base for marten. Of the seven small mammal prey species that inhabit the island, only two are endemic: the meadow vole (*Microtus pennsylvanicus*) and the arctic hare (*Lepus arcticus*). Snowshoe hare (*Lepus americanus*), masked shrew (*Sorex cinereus*), eastern chipmunk (*Tamias striatus*), and red squirrel (*Tamiasciurus hudsonicus*) were first introduced in 1864, 1958, 1962, and 1963, respectively (Northcott, 1974; Peterson, 1966; Northcott et al., 1974; Payne, 1976). A single specimen of deer mouse (*Peromyscus maniculatus*) collected in southwestern Newfoundland in 1968 appears to be the first record of *Peromyscus* on the island (Gould and Pruitt, 1969). Of these prey species, only four are found in any abundance: *Microtus*, *Sorex*, *Tamiasciurus*, and *L. americanus*. *Tamias* are found in moderate numbers in the Barachois Pond Provincial Park area and are slowly spreading throughout the western part of the province. *L. arcticus* are inhabitants of upland barrens while a small population of *Peromyscus* exist in southwestern Newfoundland.

With such a limited prey base in Newfoundland, prey abundance and availability are certainly very important to the marten population. In Newfoundland, no previous study has looked at the response of small mammals to forest harvesting. Marten prefer mature forests and utilize regenerating cutovers minimally, yet the reasons for this preference are unknown. One possible reason may involve a greater prey abundance in uncut areas than in logged areas. If so, this may explain marten preference for old-growth forests.

Goal

My primary goal was to determine how forest harvesting influences small mammal populations in western Newfoundland.

Objective

To achieve this goal, abundance and density of small mammals before and after forest harvesting were determined. Specifically:

H_o: Prey are less abundant in uncut areas versus logged areas.

H_a: Prey are more abundant or equally abundant in uncut areas versus logged areas.

STUDY AREA

The study area was located in the Grand Lake-Little Grand Lake region of western Newfoundland (Figure 1). The area was characterized by old-growth forest interspersed with ponds, lakes, barrens, and bogs, with cutovers from one to 23 years old found to the west. The main tree species included balsam fir (*Abies balsamea*), black spruce (*Picea mariana*), and white birch (*Betula papyrifera*). The terrain was rugged with elevations ranging from 120-630 meters. The climate was characterized by relatively cool summers (mean July temperature of 17 C) and moderately cold winters (January mean -6 C). Precipitation was high and evenly distributed throughout the year.

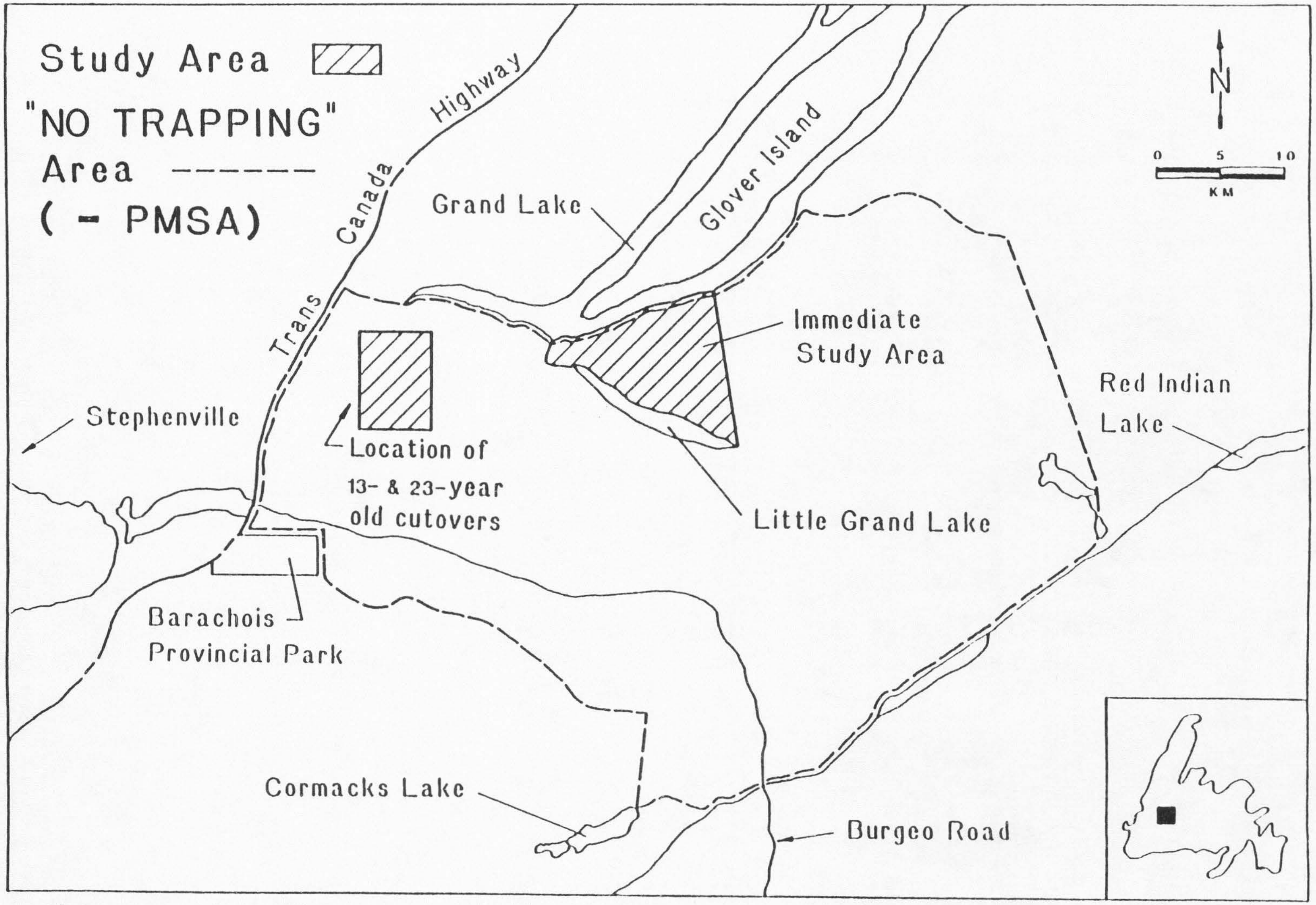


Figure 1. Location of study area in western Newfoundland.

METHODS

Field work was conducted from January 1986 to August 1987. The first forest harvest treatment in the study area occurred during late summer 1986. Small mammal trapping was carried out before, immediately after, and one-year post-harvesting in the study area. Additional small mammal trapping was conducted in 1987 in 13- and 23-year-old cutovers.

During the winter months, homogeneous areas of habitat were chosen for establishment of trapping webs (see below). At the same time, marten were tracked to determine hunting behavior. Trapping webs were placed in various habitats during spring, summer, and fall to determine small mammal abundance and density before and after forest harvesting. Marten scats were collected throughout the study and analyzed during the winter to determine composition.

Estimates of Density and Relative Abundance For Prey Species

Trapping effort concentrated on estimating *Microtus* and *Sorex* densities. Some measure of abundance also was obtained for *L. americanus* and *Tamiasciurus*.

Microtus and *Sorex*

Densities of *Microtus* and *Sorex* were estimated using a trapping web designed by Anderson et al. (1983; Figure 2). This

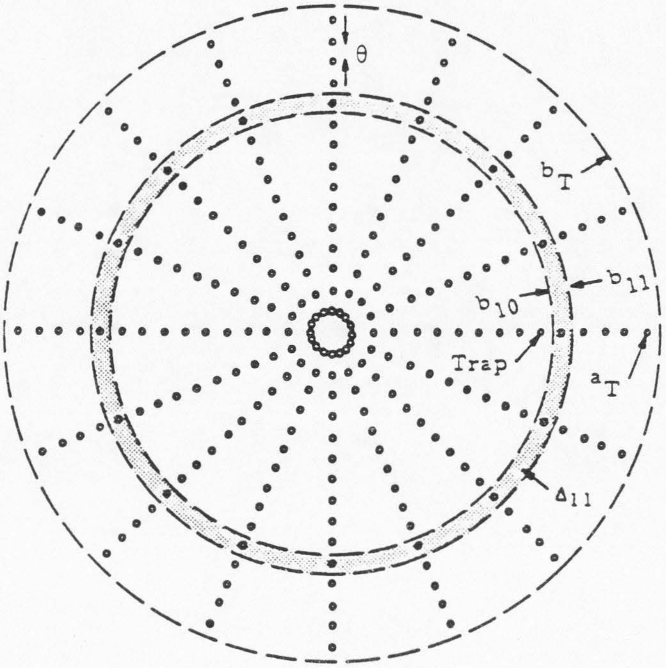


Figure 2. Trapping web with 16 lines (L=16), each of equal length a_i and 15 trap sites per line (T=15) for a total of 240 trap sites (two Victor snap traps and one pitfall trap at each trap site). Trap sites are located along each of the L lines at a distance interval of six meters (θ). Then trap sites are located at the following distances from the web center $a_i=(i-1)\theta + \theta/2$ for $i=1,\ldots,T$. The points along each line, halfway between trap sites are denoted as b_i, $i=0,1,\ldots,T$, where $b_o=0$ is the center of the web and b_T is the boundary of the web and lies just beyond the last trap site. Captures in the 11th ring of traps are assigned to the shaded ring Δ_{11} which has area $C_{11}-C_{11}$ where $C_i=\pi(b_i)^2$.

design enables density to be estimated using distance sampling analysis methods. Unlike the traditional capture-recapture and removal methods, distance sampling can be used to estimate population density directly, rather than estimating population size and geographic area separately. In plotless sampling the data are the distances d_1, d_2, ..., d_n to the n entities detected from either a random line or point. Estimation of density is based on the distribution of these distances.

Insectivores and certain rodents are captured very efficiently using pitfall traps and snap traps (Hamar et al., 1971). I used two Victor snap traps and one pitfall trap at each trap site. Victor snap traps were chosen over Museum Special snap traps for two reasons: 1) no difference in vole capture efficiency was found between the two types of traps in a pre-study, and 2) Victor snap traps were less expensive. Snap traps were baited with peanut butter; pitfalls were not. Traps remained open for four nights. All traps were tended daily and bait was replaced as needed.

Ideally, live trapping of small mammals would have been preferred over removal trapping; however, the cost of purchasing 2,880 (12 trapping webs x 240 trap sites/web; spring of 1987) Sherman live traps (approximately $10.00 per trap) was well beyond my budget. By using two Victor snap traps and one pitfall trap at each trap site, it was possible to capture a greater proportion of the small mammal population, resulting in a more accurate estimate of density. Considering there was plenty of mature forest in the study area to which trapping webs could be moved, the choice of using removal trapping appears to have been a good one.

The first trapping series occurred in June of 1986 with three trapping webs being placed in both a control area (area that would not be cut) and an experimental area (area that would be cut in late summer). This allowed the determination of whether the control and experimental areas had similar densities of small mammals before logging occurred. The second trapping series was conducted in early October, 1986. Three trapping webs were placed in a control area (mature timber) and three in the experimental area (area that had just been cut). Because removal trapping was being used, these trapping web locations were different from those used in the spring. The third and final trapping series occurred in June of 1987. At this time, three trapping webs were placed in four different habitats: mature timber (the control), a one-year-old cutover, a 13-year-old cutover, and a 23-year-old cutover that had been precommercially thinned in 1983 (the treatments). Again trapping web locations were different from those used in the spring and fall of 1986, but mature forested areas (the controls) used in 1987 were characteristically similar in vegetation to those used in the previous year. A brief description of each habitat is given in Appendix A.

To keep the effects of environmental factors on the small mammal trapping to a minimum, trapping web locations within habitats were selected so that all trapping webs were as vegetatively similar as possible. The following site characteristics were recorded at each trapping web location: slope, aspect, soil drainage, dominant tree species, stand age, average diameter at breast height (DBH), average stand height, stand density, canopy closure, shrub species, shrub height, shrub density, ground cover species and density, and amount of slash. The number of fallen logs, stumps, and boulders along a two meter strip running north and south of the web center was also recorded.

During each series all webs were run simultaneously to minimize the influence of weather on the comparative catches. Data collected on each web included the following: species captured, transect line and trap site, and whether the animal was captured in a snap or pitfall trap. Once collected, data were analyzed by computer (program TRANSECT) to determine densities for each species.

Tamiasciurus hudsonicus

To obtain an estimate of density for red squirrels, a 7x4 trapping grid (50 meter trap spacing) was established in a mature stand of balsam fir/black spruce timber. Tomahawk collapsible wire traps were used, and each trap was baited with a combination of jam, peanut butter, rolled oats, and dried apple. Numbered metal ear tags were placed in both ears of captured squirrels to aid in identification if recaptured. The squirrels were then released. The number of squirrels captured over a period of 11 days on the grid was divided by the grid area plus the area of a boundary strip (width equal to 1/2 the trap spacing) around the trapping grid (Dice, 1938).

Lepus americanus

The number of snowshoe hare in the study area before and one-year post-logging was estimated by counting the number of trails seen during the winter months. A trail was defined as all tracks belonging to one hare. Therefore, a second trail would only be counted if it appeared at some distant location from the first trail seen. No systematic survey of snowshoe hare numbers was carried out in the older cutovers due to a lack of time and manpower.

Scat Analyses

Marten scats were collected throughout the study. Scats collected by Newfoundland and Labrador Wildlife Division personnel in November and December of 1985 were also analyzed. Only 11 of 194 scats collected were found in 1987. Fewer scats were encountered in 1987 for two reasons: 1) marten numbers were much reduced, and 2) the study design required that more time be spent in clearcuts in 1987. Each scat was examined and the contents (hair, teeth, seeds, feathers, and insect exoskeletons) identified by comparing them to known samples collected earlier. Scat composition was expressed by percent frequency of occurrence. Determination of scat contents by percent volume more accurately approximates the ingested weight of prey of various sizes by a marten-sized mustelid than does the percent frequency of occurrence (Zielinski, 1981). However, the two modes of expression give the same order of importance for the main food items (Pulliainen, 1981). Taylor (pers. comm., May 1988) suggests that use of the volumetric technique involves unavoidable errors associated with differential digestion. Percent frequency of occurrence determinations were chosen for two reasons: 1) interest was in the relative importance of food items, and 2) time constraints.

RESULTS

On the island of Newfoundland the depauperate fauna provides a limited prey base for marten. Meadow vole, masked shrew, snowshoe hare, red squirrel, arctic hare, deer mouse, and the eastern chipmunk occur on the island, but only the first four in abundance. Further, only meadow voles and masked shrews were abundant in the old-growth forests of the immediate study area.

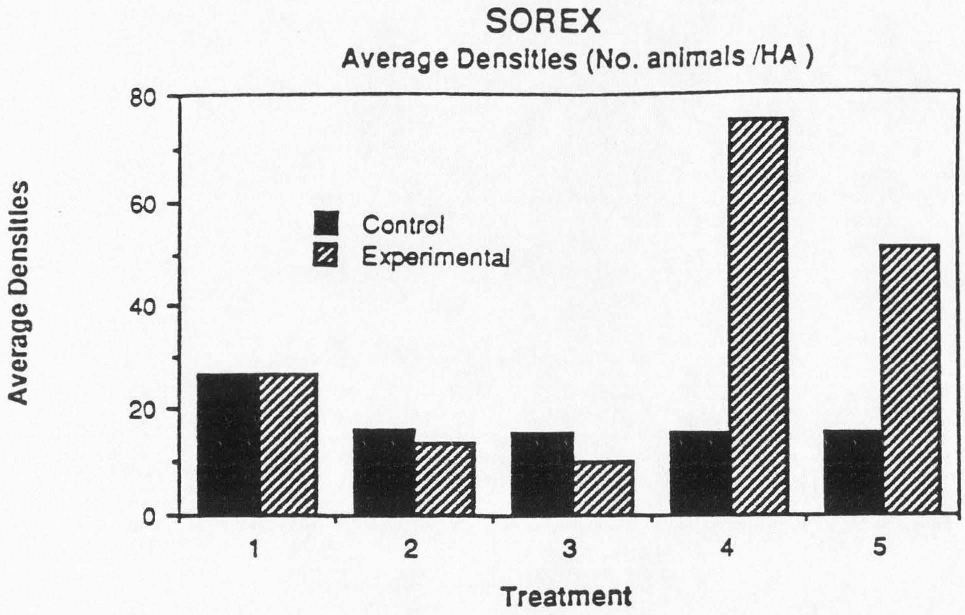
The Effects of Logging on Sorex

The average number of Sorex captured in the various habitat types as well as average densities are given in Figures 3 and 4.

1) Comparison of Sorex abundance in Control vs. Experimental areas prior to logging (Spring 1986).

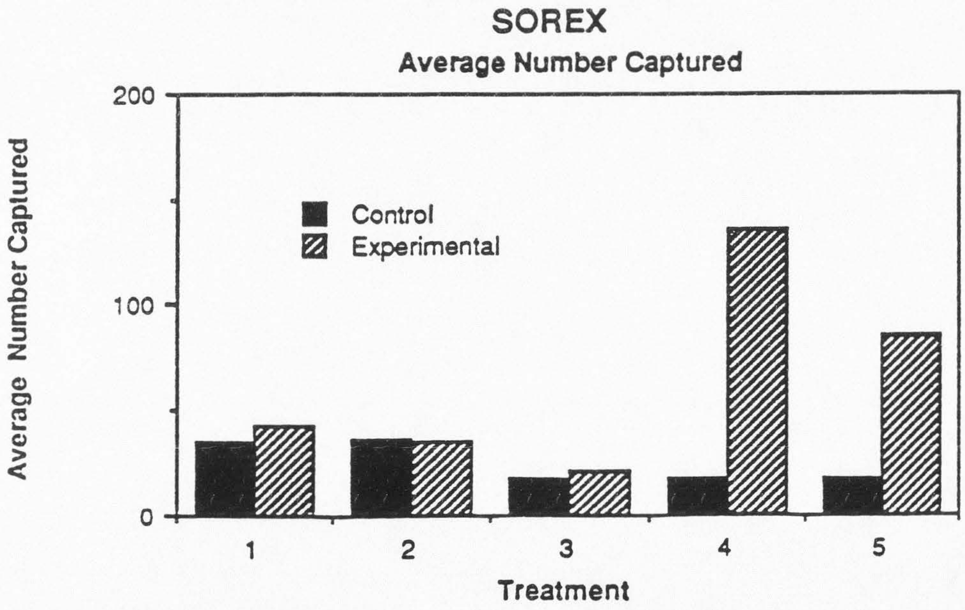
Average Densities(animals/hectare)	Average Numbers Captured
26.6 vs. 26.8	35.3 vs. 43.3

We detected no significant difference (P=0.05) in Sorex abundance in the control and experimental areas before logging occurred. The areas were similar and no impact had occurred.



1- before logging
2- 3-weeks post-logging
3- 1-year post-logging
4- 13-years post-logging
5- 23-years post-logging

Figure 3. Average densities of <u>Sorex</u> in the various habitats.



1- before logging
2- 3-weeks post-logging
3- 1-year post-logging
4- 13-years post-logging
5- 23-years post-logging

Figure 4. Average number of <u>Sorex</u> captured in the various habitats.

2) Comparison of _Sorex_ abundance in Control vs. Experimental areas three-weeks post-logging (Fall 1986).

Average Densities(animals/hectare)	Average Numbers Captured
15.9 vs. 13.4	36.0 vs. 35.0

No significant difference was found between the abundance of shrews in the mature forest and the area that had just been logged, suggesting that logging had no apparent short-term effect on _Sorex_ numbers immediately following timber harvesting. Evidently, insufficient time had elapsed between the time the area was logged and the time we initiated trapping (three weeks) for any effects of logging to be detected. Vegetative cover is important to the existence of small mammals and the slash left on the ground after logging appears to provide ample cover.

3) Comparison of _Sorex_ abundance in Control vs. Experimental areas one-year post-logging (Spring 1987).

Average Densities(animals/hectare)	Average Numbers Captured
15.7 vs. 10.3	18.0 vs. 21.7

At one-year post-logging, we detected no significant difference in the abundance of shrews between the mature timber and the logged area. A Type II error, i.e., incorrectly concluding there is no effect when one exists, is possible because of the small sample size (three trapping webs). A significant difference between the two habitats could have gone undetected. Sampling three webs per area for two areas (control and experimental) is a formidable effort; irregardless, three replicates per area constitute a relatively small sample for statistical analysis purposes.

4) Comparison of Sorex abundance in Control vs. Experimental areas 13-years post-logging (Spring 1987).

Average Densities(animals/hectare)	Average Numbers Captured
15.7 vs. 75.1	18.0 vs. 136.3

A significant difference was found between shrew abundance in the mature timber and 13-year-old cutovers. Almost five times as many Sorex were found in the 13-year-old cutover, demonstrating it to be a more favorable habitat for this species.

5) Comparison of Sorex abundance in Control vs. Experimental areas 23-years post-logging (Spring 1987).

Average Densities(animals/hectare)	Average Numbers Captured
15.7 vs. 51.3	18.0 vs. 85.7

A significant difference was found between shrew abundance in the mature timber and the precommercially thinned 23-year-old cutovers. Sorex were approximately three times more abundant in the precommercially thinned 23-year-old cutover than in the mature uncut timber.

From these data, it appears that regenerating forest stands promoted an increase in Sorex numbers over intermediate to long range periods although densities were not significantly different in the short-term.

6) Comparison of *Sorex* abundance between Control areas: Spring 1986 vs. Fall 1986.

Average Densities(animals/hectare)	Average Numbers Captured
26.6 vs. 15.9	35.3 vs. 36.0

Comparison of the control area in the spring of 1986 with the control area in the fall of 1986 indicated no significant difference between them. Although shrew density was lower in the fall, the average number of shrews captured was similar. We expected an increase in shrew numbers throughout the summer, to the onset of winter. As evidenced by *Microtus* data presented below, something apparently happened during the summer of 1986 that not only prevented the *Sorex* population from increasing, but may have caused the population to decrease somewhat. A Type II error is possible.

7) Comparison of *Sorex* abundance between Control areas: Spring 1986 vs. Spring 1987.

Average Densities(animals/hectare)	Average Numbers Captured
26.6 vs. 15.7	35.3 vs. 18.0

No significant difference was detected between the 1986 spring control and the 1987 spring control. Again, the possibility of a Type II error exists due to a small sample size.

8) Comparison of _Sorex_ abundance between Control areas: Fall 1986 vs. Spring 1987.

Average Densities(animals/hectare)	Average Numbers Captured
15.9 vs. 15.7	36.0 vs. 18.0

There was virtually no difference between the density of shrews in the 1986 fall control and the 1987 spring control. However, when average number of animals captured were compared, the number of _Sorex_ captured in the fall of 1986 (n=36) was twice the number captured in the spring of 1987 (n=18). A Student's t- test indicated no significant difference (P=0.05). However, at an alpha level of 0.15, a significant difference is indicated. Two possibilities are suggested: 1) a Type II error due to the small sample size, and 2) the densities obtained using the trapping web design may be incorrect.

Comparisons 6, 7, and 8 suggest a distinct reduction in _Sorex_ numbers even though differences do not appear significant at P=0.05. Furthermore, comparison 1 suggests the non-significant differences noted in comparisons 6, 7, and 8 may be biologically significant.

Apparently some factor other than logging influenced the _Sorex_ population between the spring of 1986 and the fall of 1986. We expected an increase in shrew numbers throughout the summer to the onset of winter, yet no increase occurred. If something had not happened to the _Sorex_ population, the density of shrews in the 13-year-old and 23-year-old cutovers may have been much higher than observed. Regardless, regenerating clearcuts promoted an increase in

Sorex numbers. Sorex were three to five times more abundant in regenerating clearcuts than in old-growth forests.

The Effects of Logging on Microtus

The average number of Microtus captured in the various habitats as well as average densities are given in Figures 5 and 6.

1) Comparison of Microtus abundance in Control vs. Experimental areas prior to logging (Spring 1986).

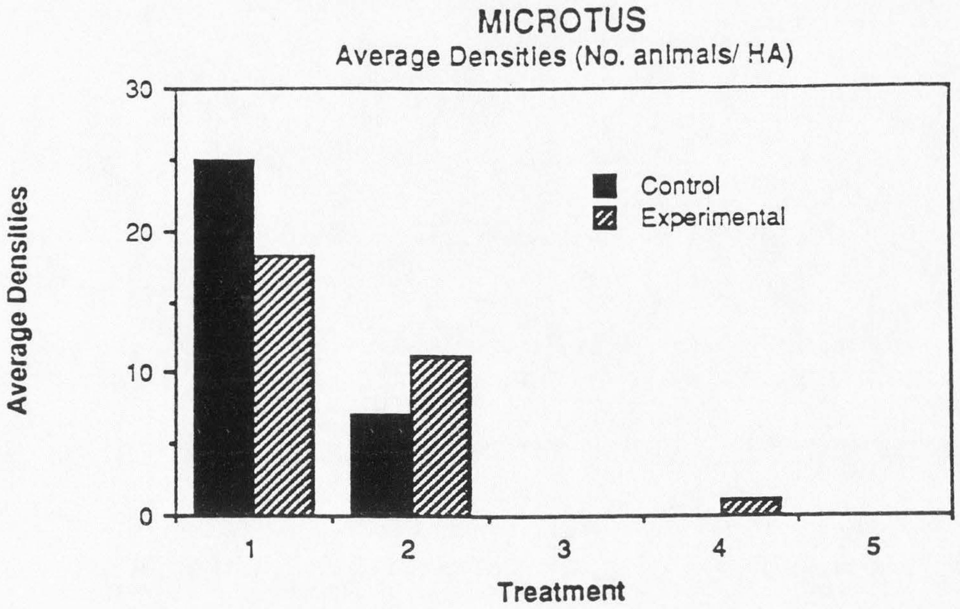
Average Densities(animals/hectare)	Average Numbers Captured
25.0 vs. 18.2	57.0 vs. 54.0

No significant difference in vole abundance was found between the control and experimental areas before logging occurred. Comparison of the average number captured in the control (n=57) with the average number captured in the experimental (n=54) further suggests no significant difference between the two areas. Again, this is what we would expect before logging since both areas were similar.

2) Comparison of Microtus abundance in Control vs. Experimental areas three-weeks post-logging (October 1986).

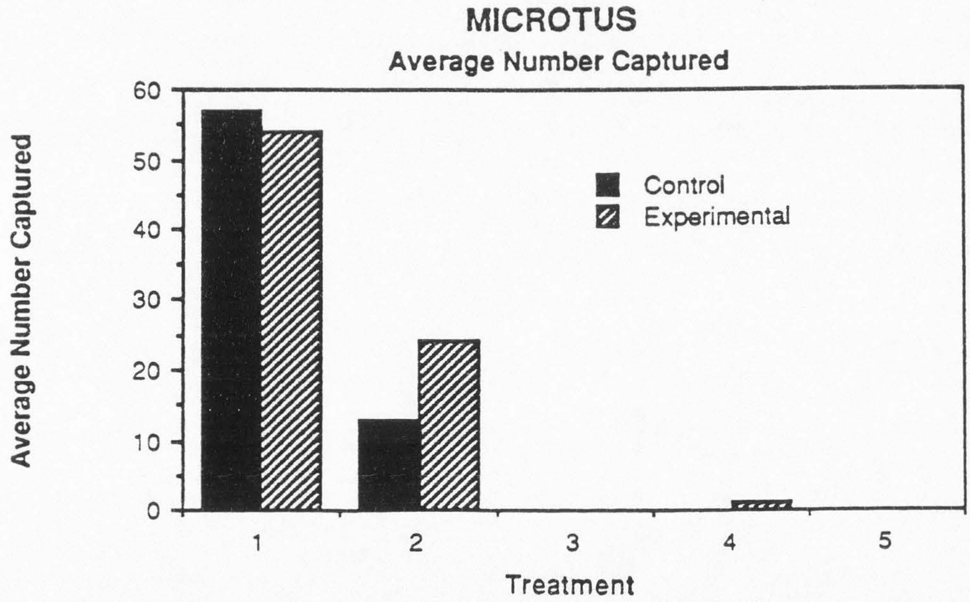
Average Densities(animals/hectare)	Average Numbers Captured
7.1 vs. 11.2	12.7 vs. 24.3

While there appears to be no significant difference in vole



1- before logging
2- 3-weeks post-logging
3- 1-year post-logging
4- 13-years post-logging
5- 23-years post-logging

Figure 5. Average densities of Microtus in the various habitats.



1- before logging
2- 3-weeks post-logging
3- 1-year post-logging
4- 13-years post-logging
5- 23-years post-logging

Figure 6. Average number of Microtus captured in the various habitats.

densities between the 1986 fall control (mature timber) and the 1986 fall experimental (cutover immediately following logging), comparison of the average numbers captured showed almost twice the number of voles in the cut area (n=24.3) as in the uncut area (n=12.7). Although no significant difference is indicated here either, it does suggest the possibility of a Type II error.

3) Comparison of Microtus abundance in Control vs. Experimental areas one-year post-logging (Spring 1987).

Average Densities(animals/hectare)	Average Numbers Captured
0.0 vs. 0.0	0.0 vs. 0.0

No voles were captured in the mature forest or the one-year-old cutovers in the spring of 1987. Apparently something caused a drastic reduction in the vole population during the winter.

4) Comparison of Microtus abundance in Control vs. Experimental areas 13-years post-logging (Spring 1987).

Average Densities(animals/hectare)	Average Numbers Captured
0.0 vs. 1.2	0.0 vs. 1.3

No voles were captured in the mature forest and only an average of 1.3 were captured in the 13-year-old cutovers in the spring of 1987.

5) Comparison of Microtus abundance in Control vs. Experimental areas 23-years post-logging (Spring 1987).

Average Densities(animals/hectare)	Average Numbers Captured
0.0 vs. 0.0	0.0 vs. 0.0

No voles were captured in the mature forest or the 23-year-old cutovers in the spring of 1987, further suggesting a serious decline in numbers over the winter months.

6) Comparison of Microtus abundance between Control areas: Spring 1986 vs. Fall 1986.

Average Densities(animals/hectare)	Average Numbers Captured
25.0 vs. 7.1	57.0 vs. 12.7

A comparison of the 1986 spring and fall control densities indicated no significant difference, however a significant difference seems apparent. A Type II error is possible. We obtained a significant difference at the $P=0.07$ level when we compared the average number of voles captured in the spring control ($n=57.0$) to the average number captured in the fall control ($n=12.7$). More than four times the number of Microtus were captured in the spring control compared to the fall control, suggesting a biologically significant, if not a statistically significant difference. The lower number of Microtus captured in the fall is unusual since vole numbers usually increase throughout the summer until the onset of winter.

7) Comparison of <u>Microtus</u> abundance between Control areas: Spring 1986 vs. Spring 1987.

<u>Average Densities(animals/hectare)</u>	<u>Average Numbers Captured</u>
25.0 vs. 0.0	57.0 vs. 0.0

A significant difference was found between the 1986 and 1987 spring controls. It appeared that the <u>Microtus</u> population was locally extirpated since none were captured in the spring of 1987. Vole numbers decreased from a density of 25.0 per hectare at the beginning of the study to 0.0 per hectare at the end of the study.

8) Comparison of <u>Microtus</u> abundance between Control areas: Fall 1986 vs. Spring 1987.

<u>Average Densities(animals/hectare)</u>	<u>Average Numbers Captured</u>
7.1 vs. 0.0	12.7 vs. 0.0

A significant difference was found between the 1986 fall control and the 1987 spring control. Vole numbers decreased from a density of 7.1 per hectare in the fall of 1986 to 0.0 per hectare in the spring of 1987. These data support the conclusion that some factor, in addition to or other than logging, affected the <u>Microtus</u> population.

During the same period, a disease outbreak of encephalitis caused heavy marten mortality in the fall of 1986. Although no disease was noted for <u>Microtus</u>, its occurrence is at least remotely possible. We were unable to relate the decline in Microtus numbers to marten mortality or vice versa.

Alternate Prey Species

Some measure of abundance was obtained for several other prey species found within the study area. Although these species are usually secondary in importance as prey, they are taken in greater frequency when microtine numbers are low.

Tamiasciurus hudsonicus

Red squirrels were commonly seen throughout the study area although not in great abundance. Tracks were seen almost daily during the winter months, and a trapping program in the summer of 1987 resulted in the capture of eight different squirrels on an effective area of 7 ha, giving an estimate of 1.1 squirrels per hectare.

Lepus americanus

A trapping program for snowshoe hare scheduled for the winter of 1986 was cancelled when it became obvious that hares were virtually non-existent on the study area. Instead, trails seen while travelling throughout the area in winter were counted to give an estimate of hare abundance before and after logging. Before timber harvesting, only 9 trails were seen over a period of 81 days (0.11 trails per day). In the winter of 1987, after logging, 53 trails were seen over 65 days (0.82 trails per day) indicating that snowshoe hare had increased slightly after harvesting. Most of the trails seen in 1987 were along the edge of the recent cutover area with dense stands of regenerating balsam fir close by. Hare were by no means abundant or even common on the study area.

At the beginning of this study, there were no clearcuts in the immediate study area; therefore, no estimate of snowshoe hare abundance could be determined in regenerating clearcuts. However, in older clearcuts outside the study area where vegetative cover was abundant, hare sign was plentiful. No sign of marten was observed in these older clearcuts during our study.

Peromyscus maniculatus

Until this study, it was not certain whether a breeding population of deer mice existed in Newfoundland. Forty-four deer mice were trapped during our field work indicating the presence of at least a small population on the west coast of the island (Tucker et al., in press). Only ten mice were captured on the trapping webs and seven of these were trapped in the 13-year-old cutover. The rest were trapped in various locations throughout the study area.

Tamias striatus

Several chipmunks were seen outside the study area and one was captured in the 23-year-old cutover area. Only one chipmunk was seen inside the study area; none were trapped.

Lepus arcticus

There was no sign of arctic hare within the study area, although they were commonly found on the Buchans Plateau located just east of the study area.

Scat Analyses

One hundred ninety-four marten scats, collected between November 1985 and August 1987, were analyzed to determine composition. Percent composition is given in Table 1. *Microtus*, found in 91.2 percent of the scats, was undoubtedly the most important prey species to the marten. Berries were the second most important food item, occurring in 19.6 percent of the scats. *Sorex* appeared in 15.5 percent of the scats while other food items occurred less frequently.

Marten Tracking

During this study, marten were tracked for a total of 12 kilometers; 90 percent of which was in mature forest. On sixteen occasions marten travelled under the snow, and in six cases climbed trees. No hunting behavior was observed in cutover areas.

Table 1. Composition of marten scats by frequency of occurrence (%).

	SEASON				
Food Item	Spring[1] (n=20)	Summer[2] (n=87)	Fall[3] (n=57)	Winter[4] (n=30)	Total (n=194)
Microtus/*Peromyscus*	95.0	93.1	100.0	66.7	91.2
Sorex	30.0	5.7	21.1	23.3	15.5
Tamiasciurus	5.0	1.1	----	20.0	4.1
Lepus	----	----	----	3.3	0.5
Birds	5.0	9.2	5.3	6.7	7.2
Berries	5.0	41.4	1.8	----	19.6
Insects	----	5.7	----	----	2.6
Carrion	----	----	3.5	13.3	3.1
Unknown	----	1.1	----	13.3	2.6

[1] March 23 - June 20
[2] June 21 - September 22
[3] September 23 - December 22
[4] December 23 - March 22

DISCUSSION

In Labrador, where marten numbers are much higher than they are on the island of Newfoundland, there are more than twice as many small mammal prey species available to marten (Table 2). With the exception of eastern chipmunks, all prey species found in Newfoundland also are found in Labrador. Chipmunks were introduced to the island in 1962, but I could find no report of chipmunks in Labrador (Peterson, 1966).

Microtus

During this study, microtines were found in 91.2 percent of the marten scats. Other workers also have found microtines to be very important prey (Soutiere, 1979; Buskirk and Macdonald, 1984; Douglass et al., 1983). A 66.7 percent occurrence of Microtus in the winter scats could be due to the lower availability of this species beneath the snow during winter.

Over the course of this study, Microtus populations declined to almost zero density, apparently independently of logging. A drastic reduction in vole numbers during this study masked whatever effect logging may have had on vole numbers. It is well known that many, but not all, Microtus populations fluctuate with a periodicity of 3-4 years (Krebs and Myers, 1974; Taitt and Krebs, 1985) such that in some years vole numbers are very low. The consequences of cyclicity will be discussed later.

Table 2. Prey species available to marten in Labrador and Newfoundland.

Labrador	Newfoundland
Meadow vole (*Microtus pennsylvanicus*)	Meadow vole
Red backed vole (*Clethrionomys gapperi*)	Deer mouse
Heather vole (*Phenacomys intermedius*)	Snowshoe hare
Rock vole (*Microtus chrotorrhinus*)	Arctic hare
Deer mouse (*Peromyscus maniculatus*)	Red squirrel
Meadow jumping mouse (*Zapus hudsonicus*)	Masked shrew
Woodland jumping mouse (*Napeozapus insignis*)	Eastern chipmunk[1]
Snowshoe hare (*Lepus americanus*)	
Arctic hare (*Lepus arcticus*)	
Red squirrel (*Tamiasciurus hudsonicus*)	
Northern flying squirrel (*Glaucomys sabrinus*)	
Starnosed mole (*Condylura cristata*)	
Northern bog lemming (*Synaptomys borealis*)	
Labrador collared lemming (*Dicrostonyx hudsonicus*)	
Masked shrew (*Sorex cinereus*)	
Water shrew (*Sorex palustris*)	
Pygmy shrew (*Microsorex hoyi*)	

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[1] (*Tamias striatus*)

Although the effects of logging on Microtus in Newfoundland could not be determined directly from this study, studies elsewhere suggest that vole numbers increase after forest harvesting. In Maine, higher numbers of meadow voles were caught in clearcut softwood stands than in uncut stands (Monthey, 1978; Monthey and Soutiere, 1985). Likewise, voles were more abundant in clearcuts than in mature forests in Ontario (Martell and Radvanyi, 1977; Thompson, 1986). However, this pattern may not hold for insular Newfoundland with its depauperate prey base. With lack of interspecific competition on islands, Microtus appear to be found in a variety of habitats that they don't usually occupy on the mainland. Microtus are normally found in open grasslands on the mainland, whereas they occupy both grassy and forested habitats on islands (Grant, 1971). Population response to logging in island habitats may not be comparable to those found on the mainland.

Sorex

Sorex were the second most important prey occurring in 15.5 percent of the marten scats. Logging appeared to have no short-term effect on Sorex. No significant difference in Sorex abundance was found between the undisturbed forest and the recent cutover (P=0.52), and the undisturbed forest and the one-year-old cutover (P=0.58). However, a significant difference in Sorex abundance was found between undisturbed forest and older regenerating cutovers (13- and 23-year old sites; P=0.005 and P=0.041, respectively). Sorex densities were three to five times higher in regenerating clearcuts than in old-growth forests. High moisture levels under the dense regenerating conifer canopy may be involved. Masked shrews tend to prefer habitats with high humidity (Folinsbee, 1971; Wrigley et al., 1979).

Alternate Prey Species

Other prey species occurred less frequently in marten scats collected during this study indicating they were less abundant or less available.

Tamiasciurus hudsonicus

Red squirrels were commonly seen throughout the study area, but occurred in only 4.1 percent of the scats overall. However, squirrel remains were found in 20.0 percent of the scats collected in winter indicating their importance to marten when vole availability is reduced due to snow cover. Bateman (1986) did not identify red squirrels in marten scats she examined, but squirrels were common in her study area in southwestern Newfoundland. More squirrels were found in uncut forest than in logged areas in Ontario (Thompson, 1986).

Lepus americanus

Snowshoe hare, virtually non-existent in the mature forest of the study area, was found in only one scat (0.5 percent). This scat was collected during the 1986-87 winter; no scats containing hare remains were found during the 1985-86 winter. In Southwest Brook, just south of my study area, hare were the most important prey item in winter with meadow vole ranking second in importance (Bateman, 1986). Hare comprised 58.9 percent of the marten diet in southeastern Manitoba at a time when hare numbers were high (Raine, 1987). In Ontario, snowshoe hare were an important prey item for marten (Thompson, 1986). In nearly all other studies, hare were found in small to moderate quantities in the diet of marten (Weckwerth and Hawley, 1962; Soutiere, 1978; Zielinski, 1981).

Gashwiler (1959) found only a few snowshoe hare in a virgin forest site in west-central Oregon. The first year after logging, neither hares nor their sign were observed in the clearcuts. Observations suggested that hares near the forest edge moved into the clearcut as soon as cover conditions permitted, and resided in patches of suitable cover (Gashwiler, 1970).

Peromyscus maniculatus

Until this study, there had only been two previous reports of Peromyscus on the island. Gould and Pruitt (1969) collected a single specimen in southwestern Newfoundland in 1968. Bateman (1983) collected four deer mice in the same area in 1981. Forty-four deer mice were trapped during this study indicating at least a small population on the west coast of the island. Regardless, relatively few deer mice were caught, and they did not comprise a major part of marten diets.

Tamias striatus

Eastern chipmunks were introduced to the island in 1962 but, unlike red squirrels, do not seem to be dispersing throughout the island very quickly. Few observations of chipmunks were made during this study and no sign of chipmunk remains was found in the marten scats.

Lepus arcticus

There was no sign of arctic hare in the study area although arctic hare are commonly found on the Buchans Plateau. Unlike marten, arctic hare prefer habitat devoid of spruce and fir; therefore, encounters between the two are probably rare.

Other Food Items

Berries, birds, insects, and carrion also were found in marten scats. Berries comprised 19.6 percent and seemed to be seasonally important. Birds were found in 7.2 percent of the scats while insects and carrion occurred in 2.6 and 3.1 percent, respectively. Carrion was found in scats collected primarily during the winter.

Microtine Cyclicity

During this study, Microtus populations declined from a density of 25.0 per hectare in the spring of 1986 to practically zero in the spring of 1987. Despite a trapping effort in four different habitats resulting in 34,560 trap nights, only six Microtus were captured in 1987 for a rate of 0.174 Microtus/1000 TN (trap nights). This is in contrast to 16.1 Microtus/1000 TN during the previous year. Fifty Victor snap traps (open for two nights) were placed 85 kilometers north, 40 kilometers southwest, and 30 kilometers southeast of the area to determine whether the decline in Microtus numbers was restricted to the study area. No voles were captured, suggesting that the decline was more widespread.

Information from other parts of North America was gathered to determine the extent of the decline. In Labrador, a reduction in the rodent fauna during the same time period suggested a province- and perhaps region-wide decline and cyclicity (Lemon and Phillips, pers. comms., Oct 1987). A synchronous fluctuation in small mammal biomass between the island of Newfoundland and mainland Labrador has been reported before by Pruitt (1972). Microtus in Quebec were extremely low in number in 1986 and 1987 (Bergeron, pers. comm., March 1988) suggesting a population fluctuating independently of those in Newfoundland and Labrador. Asynchrony in vole fluctuations is also apparent from data collected elsewhere. Voles were abundant on an island in southern Ontario in the spring of 1986, but declined dramatically by mid-summer of the same year (Plante, pers. comm., March 1988). On another island only 50 kilometers away, voles were abundant throughout 1986, but crashed during 1987. In northern Manitoba, vole populations crashed in 1986 but appeared to be recovering in 1987 (Mallory, pers. comm., March 1988). A similar trend was seen in Alberta by Millar (pers. comm., March 1988). Microtus numbers were high in 1987 in the Yukon Territory (Krebs, pers. comm., March 1988) and on Baffin Island (Shank, pers. comm., March 1988). Microtus have been low in number for the past three years in Illinois (Getz, pers.comm., March 1988) and in Massachusetts (Tamarin, pers. comm., March 1988).

From the above information, two conclusions appear warranted.

First, any synchronous fluctuations in small mammal numbers between two or more geographic areas may be coincidental and totally unrelated. Second, not all small mammal populations cycle on a 3-4 year periodicity. Taitt and Krebs (1985) concluded, based on 106 years of data, that Microtus populations displayed annual cycles 59 percent of the time; phases of multiannual population fluctuations were evident during 41 percent of the years. Other studies have found similar results (Boonstra, 1985; Meserve and Klatt, 1985; Getz et al., 1987). A third conclusion also may be drawn based on published literature. Small mammal fluctuations among species within an area may or may not be synchronized. No obvious synchrony of fluctuations among species was noted in Manitoba (Mihok et al., 1985) while synchrony of fluctuations was reported in populations of various species of small herbivores in Fennoscandia (Lack, 1954).

Synchronous fluctuations in small mammal biomass were found between the island of Newfoundland and mainland Labrador (Pruitt, 1972). Labrador and Newfoundland are separated by a narrow, but significant, zoogeographic barrier (the Strait of Bell Isle) which prevents mammalian gene flow (Pruitt, 1972). Considering the above information on asynchronous fluctuations in small mammal numbers, the synchrony in small mammal fluctuations between Labrador and Newfoundland appears coincidental. Further research appears needed on this subject.

Many causative factors have been proposed to explain small mammal cyclicity. These include disease (May and Anderson, 1979), predation (Lindstrom et al., 1987), genetics (Chitty, 1960), dispersal (Meserve and Klatt, 1985), nutrition (Lindroth and Batzli, 1986), weather (Fuller, 1977), infanticide (Boonstra, 1980), seasonality (Boonstra and Boag, 1987), and splenic hypertrophy (Dawson, 1956). However, no single factor or group of factors has received general support (Getz et al., 1987).

Microtine cycles are characterized by a number of features: larger body weight in peak years (Boonstra and Krebs, 1979), higher age at sexual maturity during peak and decline years (Boonstra, 1978), shorter breeding season during decline years (Krebs, 1978), lower survival of young during decline years (Krebs et al., 1969), increased growth rate during increase years (Krebs, 1978), winter breeding during the increase phase (Schaffer and Tamarin, 1973), and lower survival of adults and juveniles during decline years (Krebs and Myers, 1974). The change in body size of adults is one of the most striking phenomena that accompanies population cycles in voles and lemmings (Krebs and Myers, 1974). However, not all fluctuating populations show this effect (Gaines and Rose, 1976). In this study, 35.5 percent (118/332) of the Microtus captured in the spring of 1986 weighed more than 50 grams indicating that the Microtus population in Newfoundland was possibly at a peak in numbers at that time. In the fall of 1986, when fewer voles than expected were captured, only 0.03 percent (3/117) of the animals weighed greater than 50 grams. This suggests that the vole population was declining in number and displaying features typical of a cyclic fluctuation. In the spring of 1987, virtually no Microtus were captured indicating that the vole population did, indeed, "crash". Unfortunately no data on vole numbers in Newfoundland are available for 1985, therefore, whether the density of voles in 1985 was higher or lower than 1986 is unknown.

Significance of Microtine Cyclicity To Marten

During this study *Microtus* were found in 91.2 percent of marten scats indicating that voles were very important prey to marten. *Microtus* are cyclic, or at least fluctuate in population density in Newfoundland, and there are years when their numbers are very low. The effects on marten are largely unknown but undoubtedly significant.

Prey switching in predators is not uncommon. Red fox (*Vulpes vulpes*) and other predator species switched from voles to mountain hares (*Lepus timidus*) as voles declined in number (Angelstam et al., 1984). Stoat (*Mustela erminea*) and weasel (*Mustela nivalis*) also switched from small rodents to birds when voles and house mice (*Mus musculus*) were scarce (Tapper, 1979; Moors, 1982).

In this study only two small mammal prey species, *Microtus* and *Sorex*, were common in the old-growth forests suggesting that in years of *Microtus* scarcity, *Sorex* may be the only alternative prey species occurring in any abundance. With *Sorex* weighing four grams on average and providing only 5 kcal of energy (Davison et al., 1978; Powell, 1981), it is unlikely that marten could survive for long on a diet consisting mostly of *Sorex*. Red squirrels and a very few snowshoe hare also inhabited the study area. It is possible that these species become more attractive to marten in years of low

Microtus abundance. My data indicate that red squirrel is more important during the winter when voles are less available and snowshoe hare remains were found in marten scats at a time when voles were scarce.

In Ontario, out of 20 attempts by marten to kill mice, only one ended in failure, while all eleven attempts by marten to kill red squirrels were unsuccessful (Thompson, 1986). Certainly a hare or a squirrel would provide more energy to a marten. However, the costs of finding and capturing these species in an area where their numbers are low may far outweigh the benefits received.

In the fall of 1986, an outbreak of suspected viral encephalitus spread throughout the marten population in our study area resulting in the deaths of ten marten (a companion study was looking at the effects of logging on marten). It is possible that the viral infection in marten could have been linked to the decline in Microtus numbers which occurred at the same time. The impact of an infection is often related to the nutritional state of the host (May and Anderson, 1979). Broadly speaking, malnourished hosts have lowered immunological competence, and are less able to withstand the challenge of infection. Thompson (1986) suggested that marten in poor food years are highly stressed. With the decline of the Microtus population in the fall of 1986 and the lack of alternative prey species, it is possible that the marten population was under stress at that time due to malnutrition. Further research is needed before any linkage between the two occurrences can be made.

Access to the Subnivean Zone

Marten generally hunt in crevices under stumps, fallen logs, and rocks. During winter, objects at ground level are difficult at best to reach when the snowpack is deep, contains ice layers, or is densely compacted. Although marten can dig directly through the snowpack, hunting becomes energetically more costly as snow depths increase. Marten reduce energy costs by using natural crevices around objects protruding from the snow as avenues to the subnivean zone. Much circuitous travelling behavior is directed toward finding access routes to the subnivean zone around tree trunks, rocks, and logs (Hargis, 1982; Hargis and McCullough, 1984). Similar hunting behavior has also been noted in Idaho (Koehler et al., 1975), Wyoming (Campbell, 1979), Maine (Soutiere, 1978), Ontario (Francis and Stephenson, 1972), California (Spencer, 1981), and Finland (Pulliainen, 1981).

Winter thaws are common in Newfoundland and layers of ice often form in the snow, making it difficult or impossible for marten to reach objects at ground level. Access to the subnivean zone may not be as readily available in cutovers as it is in forested areas (Koehler and Hornocker, 1977). With the absence of trees and the buildup of snow in cutover areas during winter, access to the ground is made much more difficult at a time when availability of prey is especially critical.

CONCLUSIONS

Marten prefer mature coniferous and mixed forests and utilize clearcuts minimally, yet small mammal prey species in Newfoundland appear to be more abundant in clearcut areas. During this study Sorex cinereus were three to five times more abundant in regenerating cutovers. Snowshoe hare sign was much more plentiful in this habitat also. Although the effects of logging on Microtus pennsylvanicus could not be determined directly from this study, the literature suggests that Microtus also are more abundant in logged areas than in uncut areas. This suggests that prey abundance above certain threshold densities is not critical to marten habitat selection. However, prey availability may play a more important role. Habitats supporting high densities of prey may not be profitable foraging sites for predators because other factors reduce availability of prey (Baker and Brooks, 1981). Although voles and other prey species may be more abundant in logged areas, prey availability may be reduced.

Of the seven small mammal prey species that inhabit the island, only two (Microtus and Sorex) appear to occur in any abundance in the marten's preferred habitat. During this study Microtus numbers declined dramatically to almost zero density in the spring of 1987 indicating that it displays the typical cyclic pattern of many microtines. This means that in some years the vole population is greatly reduced leaving Sorex as the only other prey species available in any abundance in old-growth forests.

Energetically, Sorex only provides about 5 kcal of energy to marten and probably would not be able to fulfill the energy requirements of a marten population for long. With the scarcity of alternative prey species in the old-growth forests of Newfoundland, marten depend highly upon the fluctuating Microtus population to satisfy their energy requirements.

An outbreak of viral encephalitus in the marten population in the fall of 1986 could possibly be linked to the simultaneous decline in vole numbers. During years of low food abundance, marten are doubtlessly malnourished and have lowered immunological resistance such that they are more susceptible to viral infections (Dobson and Hudson, 1986; Begon et al., 1986).

With the destruction of prime habitat, a depauperate prey base, and a virus with the potential to annihilate a significant proportion of the marten population, marten in Newfoundland appear to have a bleak future. Introduction of alternative prey species to the island to augment the now present depauperate prey base could have deleterious effects. Presently Microtus are found in a variety of habitats in Newfoundland. The introduction of a competitor species could result in the exclusion of Microtus from the forested habitats. During the 1960's, red squirrels and eastern chipmunks were introduced into Newfoundland to help increase the food base of marten (Hancock, pers. comm., Jan 1988). The introduction of ruffed grouse (Bonasa umbellus) and spruce grouse (Dendragapus canadensis) for other purposes likewise do not appear to have provided a readily available and abundant food resource for marten.

Prior to the mid-1900's, marten were found in most forested areas of the province. Despite the closing of the marten trapping season in 1934 and the introduction of additional prey species in the 1960's, marten numbers and distribution continued to decline. Although recurring disease may have contributed to the marten's decline, the weight of published papers and my data suggest that habitat loss caused by forest harvesting within prime habitat is the main obstacle to the marten's recovery on the island. In light of this, it seems that forest harvesting guidelines meant to maintain an environment compatible with habitat requirements for marten must be administered and followed to prevent any further decline in marten numbers.

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APPENDIX

Habitat Descriptions

Mature Timber - This habitat was characterized by mature balsam fir (*Abies balsamea*), black spruce (*Picea mariana*) forest with scattered white birch (*Betula papyrifera*). Average stand age, stand height, and diameter at breast height (DBH) were 76 years, 15 meters, and 20.7 centimeters, respectively. Predominant ground cover species included wood fern (*Dryopteris austriaca*), bunchberry (*Cornus canadensis*), twinflower (*Linnaea borealis*), starflower (*Trientalis borealis*), creeping snowberry (*Gaultheria hispidula*), goldthread (*Coptis trifolia*), and several species of mosses (*Sphagnum* sp., *Dicranum* sp., *Pleurozium* sp., *Polytrichum* sp., and *Lycopodium* sp.). Ground cover density was high.

Recent Cutover - This habitat was characterized by a few scattered standing white birch. Slash was moderate to heavy. Predominant ground cover species included bunchberry, starflower, goldthread, and several species of mosses (*Sphagnum* sp., *Pleurozium* sp., *Dicranum* sp., *Polytrichum* sp., and *Lycopodium* sp.). Ground cover density was moderate.

One-year-old Cutover - This habitat consisted of scattered standing white birch with light to moderate slash. Predominant ground cover species included wood fern, starflower, bunchberry, and mosses (Sphagnum sp., Pleurozium sp., and Dicranum sp.). Ground cover density was light.

13-year-old Cutover - This habitat was characterized by thick regenerating balsam fir and white birch. The area had been cut in 1974 and the average age of the trees on the area was 11 years old. Average stand height and DBH were 2.7 meters and 3.3 centimeters, respectively. Predominant ground cover species included bunchberry, wood fern, violets (Viola sp.), fireweed (Epilobium augustifolium), goldenrods (Solidago sp.), asters (Aster sp.), currants (Ribes sp.), and raspberry (Rubus sp.). Ground cover density was high.

23-year-old Cutover - This habitat was characterized by regenerating balsam fir that had been precommercially thinned in 1983. The area had been cut in 1964 and the ground was covered with slash due to the thinning. Predominant ground cover species included bunchberry, wood fern, asters, yellow clintonia (Clintonia borealis), false lily-of-the-valley (Mianthemum canadense), and mosses (Pleurozium sp., Dicranum sp., and Lycopodium sp.). Ground cover density was moderate to high.